SpW Application from JAXA

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SpaceWire Working Group Meeting 6

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A man involved in SpaceWire
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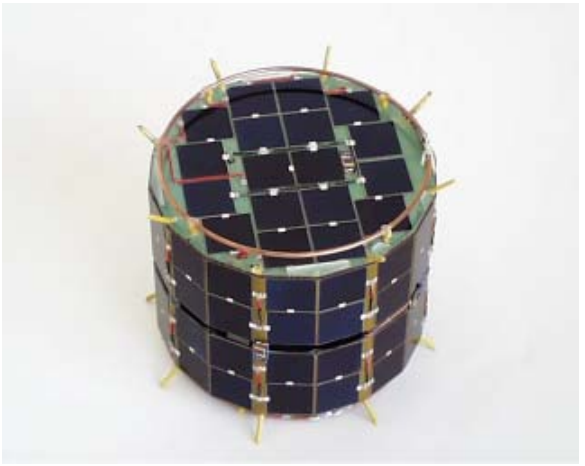
Contents



- SpW application to robots
  - current robot: asteroid rover
  - future robot project
- Space Cube series
  - CPU box with SpW I/Fs working by T-Engine realtime kernel
  - Space Cube I
  - Space Cube II
- SpW demonstration by Space Cube II

MINERVA

- MIcro/Nano Experimental Robot Vehicle for Asteroid
- Installed in HAYABUSA spacecraft

- should have become the first asteroid surface explorer
  - deployed to the asteroid surface on 12 Nov, 2005
  - did not land on the asteroid surface
  - became a solar orbiting satellite

- Very small and light-weighted
  - mass: 591[g]
  - size: diameter 120[mm] x height 100[mm]
  - can be applicable to a record in Guiness Book?

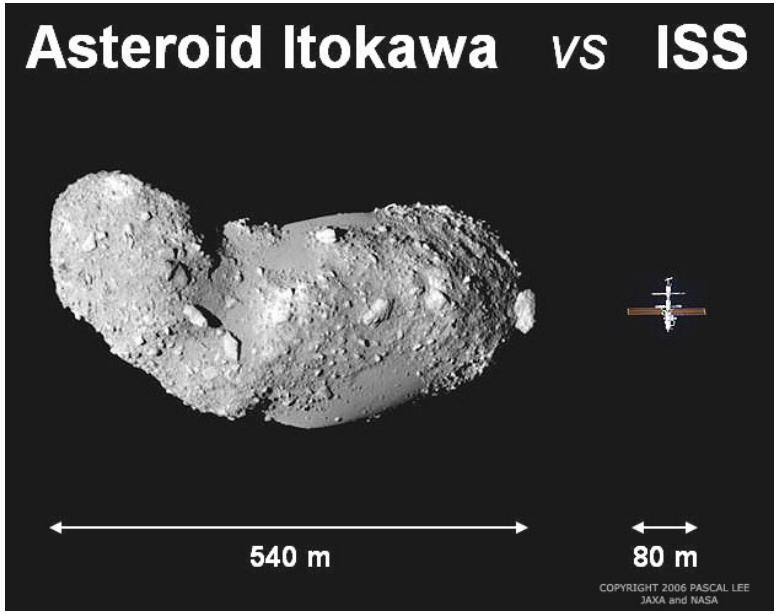
- Technical experimental rover
  - hopper
  - autonomous exploration

HAYABUSA Mission

- sample return mission to asteroid
  - size: 1000 x 1600 x H1000[mm]
  - mass: 512[kg] (with fuel),
    380[kg] (without fuel)

- launched on 9 May, 2003.
- rendezvous at ITOKAWA in Sep, 2005.
- touchdowns to ITOKAWA in Nov, 2005.
- still on the asteroid orbit till 2007.
- will be back to the Earth in 2010.

- target asteroid “ITOKAWA”
  - size: 540 x 250 x 220[m]
  - very weak surface gravity
    gravity: $4\times10^{-6} \sim 2\times10^{-5}$[G]
    escape velocity: 16 ～ 24[cm/s]



MINERVA Specifications

size	hexadecagonal pole (diameter: 120[mm], height: 100[mm])
mass	591[g]
onboard computer	32bit RISC (@10[MIPS]) ROM: 512[kB], RAM: 2[MB], FlashROM: 2[MB]
OS	iTRON (realtime OS)
actuators	DC motor ×2
mobile system	hopping (max 9[cm/s]@rigid surface)
power supply	solar cells: max: 2.2[W] @1[AU] from Sun capacitors: 5[V],25[F]
communication	9,600[bps] (half duplex, max distance: 20[km])
sensor(navigation)	photo diode×6, thermometer×4
sensor(science)	color CCD camera×3, thermometer×6
temperature range	-50 ～ +80 [C]
life	3[asteroid days] (1[asteroid day]=12.15[h])

MINERVA flight model

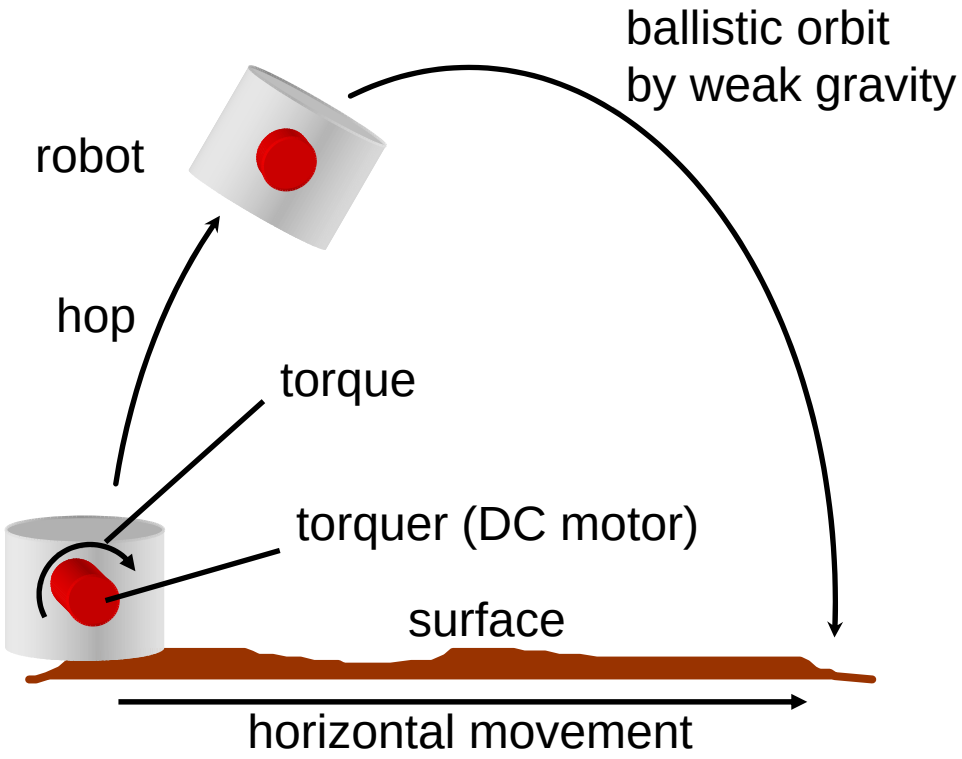
MINERVA Operation

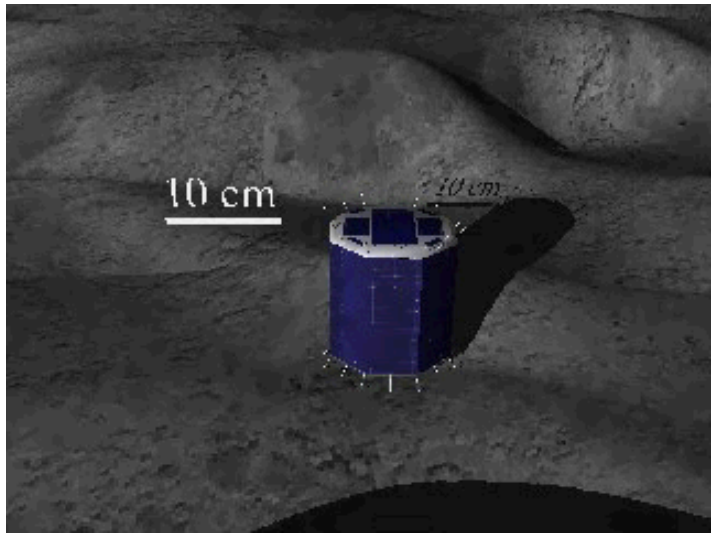
- Deployed on 12 Nov, 2006 by the command from the ground.

- But ...
  - MINERVA did not arrive at the asteroid due to the unexpectedly large velocity of Hayabusa relative to the asteroid.
  - MINERVA became a Solar-orbiting satellite.
  - Telemetry link between MINERVA and Hayabusa was established for 13 hours after the deployment
  - After the telemetry link was over, no one knows what MINERVA became.
  - The last telemetry showed MINERVA was very healthy. It may be active now.

Highlight in MINERVA

MINERVA is a hopper.

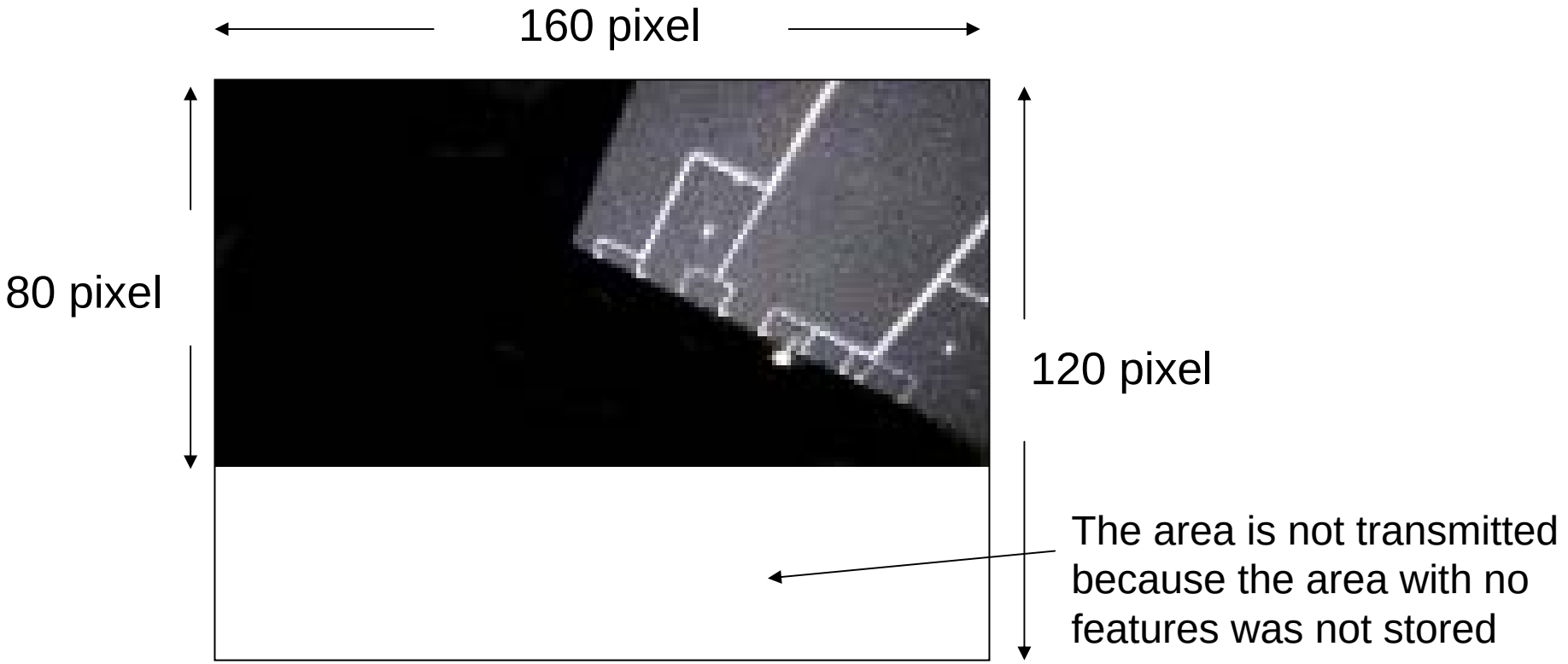




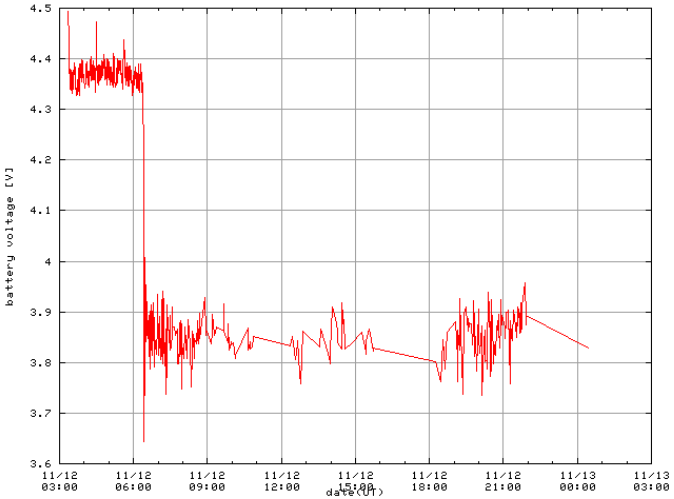
Microgravity experiment using a drop tower

MINERVA obtained data (1)

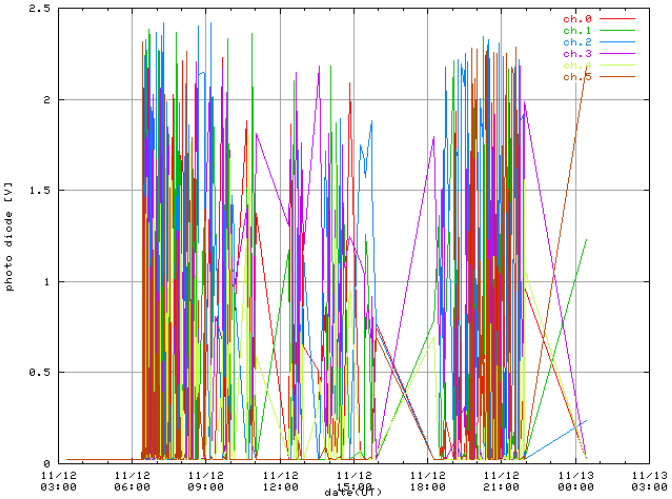
- MINERVA captured Hayabusa after the deployment.
- It was the first picture that the spacecraft in the deep space (300×10^6 km away) was directly shot from the other spacecraft.



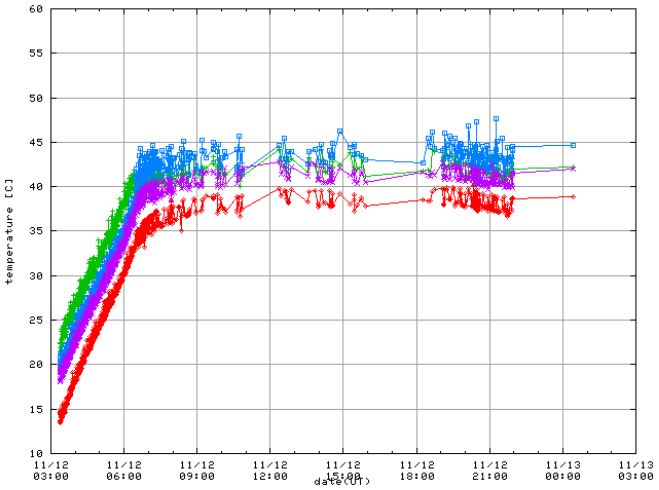
MINERVA obtained data (2)



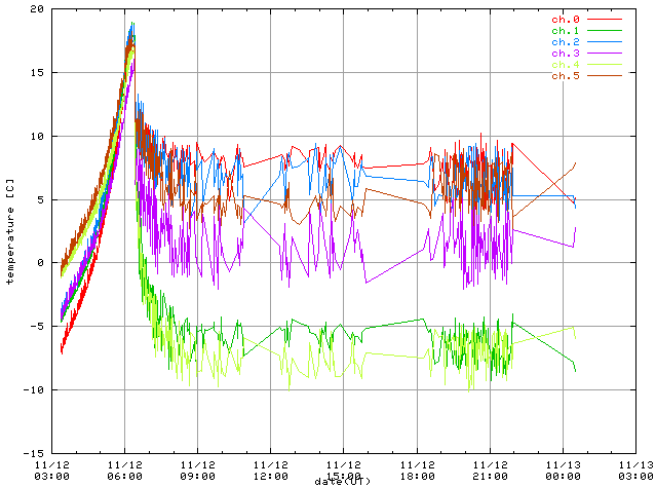
the voltage of the battery



PDs measuring the incoming light (6ch)

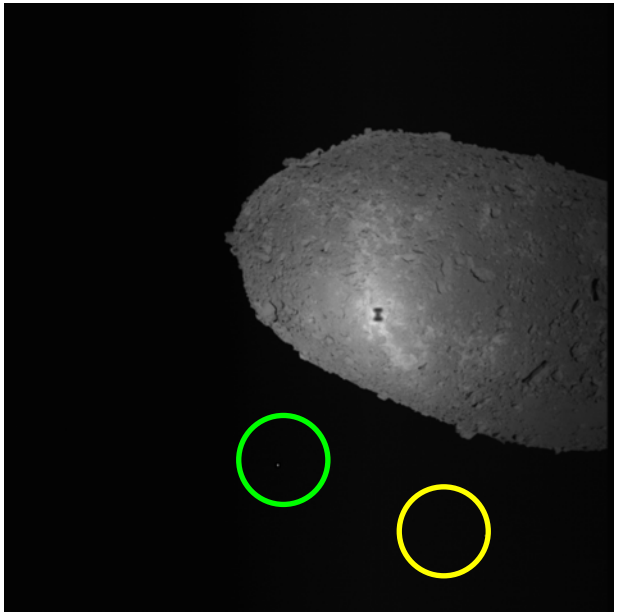


temperature inside (4ch)

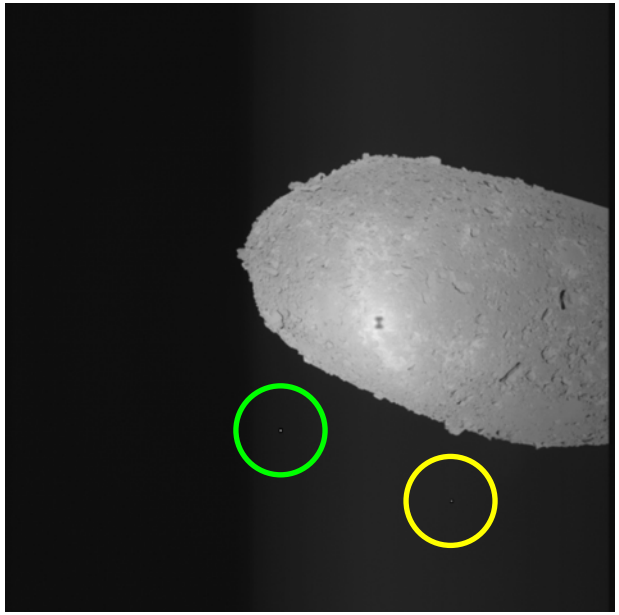


temperature outside (6ch)

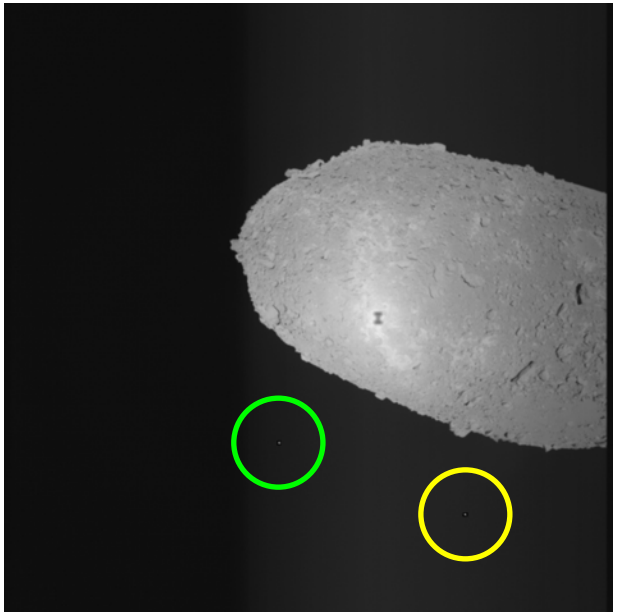
MINERVA pictures by HAYABUSA



212[sec]
after deployment



250[sec]

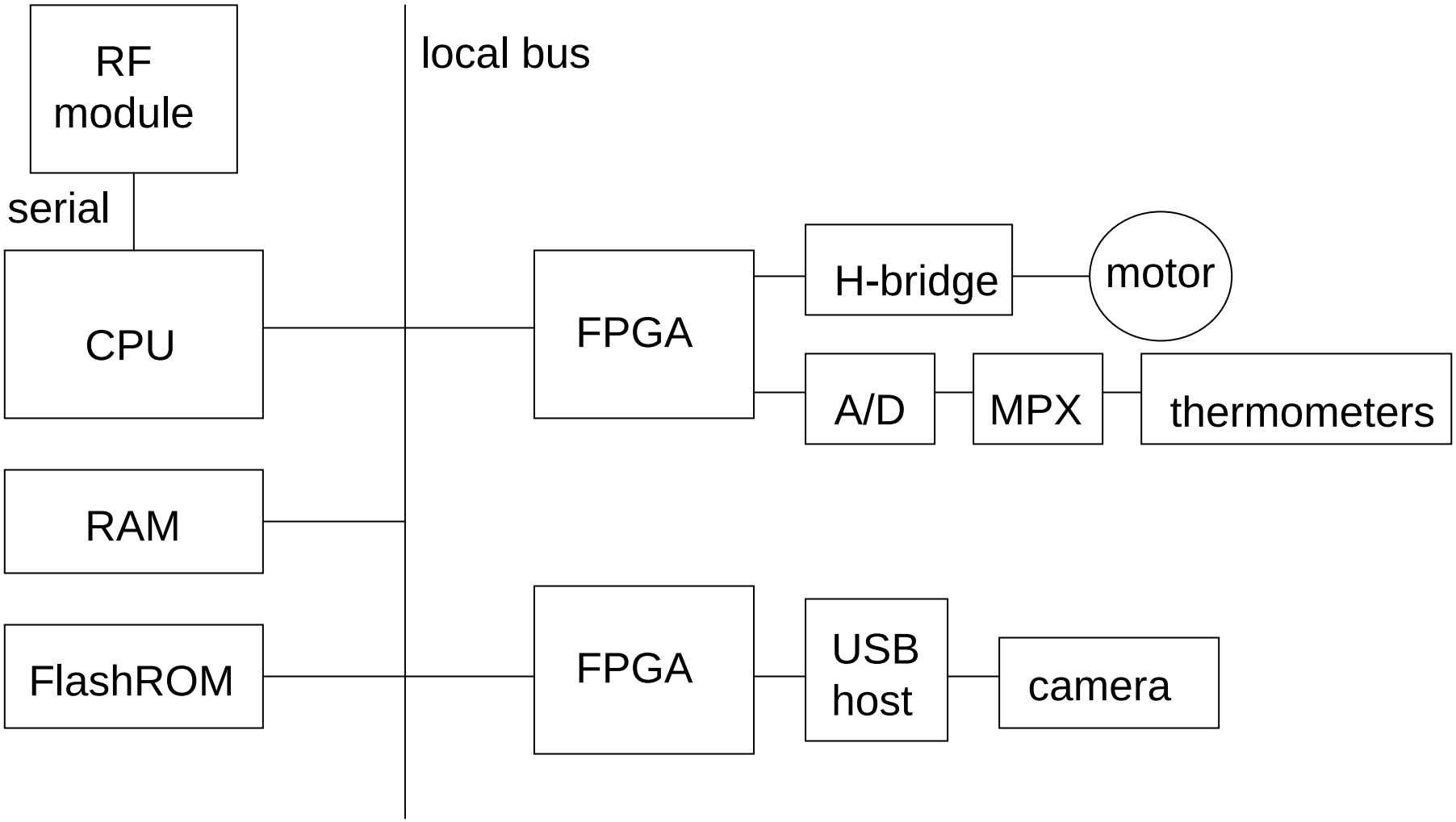


300[sec]

cover

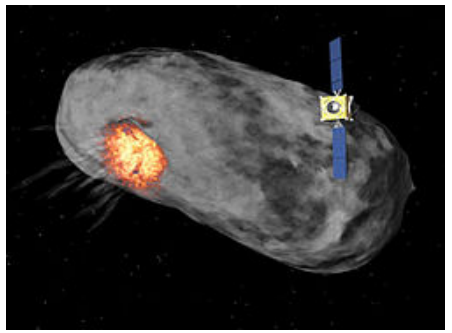
MINERVA

MINERVA


RF
module
serial
CPU
RAM
FlashROM
local bus
FPGA
FPGA
H-bridge
motor
A/D
MPX
thermometers
USB
host
camera

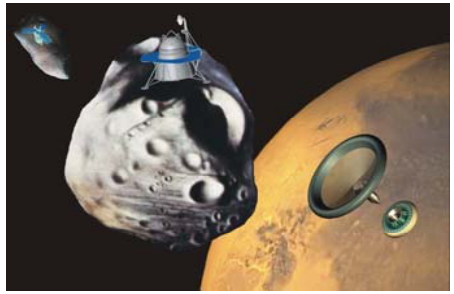
Future Plan of Robotics: Small Space Robot Probe

- weighted in a few kilograms: Pico-sized S/C
- ex.
  - Another asteroid surface rover
    (MINERVA-II,III,IV,V ...)
  - Small flyby S/C to asteroids and comets
  - Earth orbiting robot satellite
    (such as autonomous rendezvous)



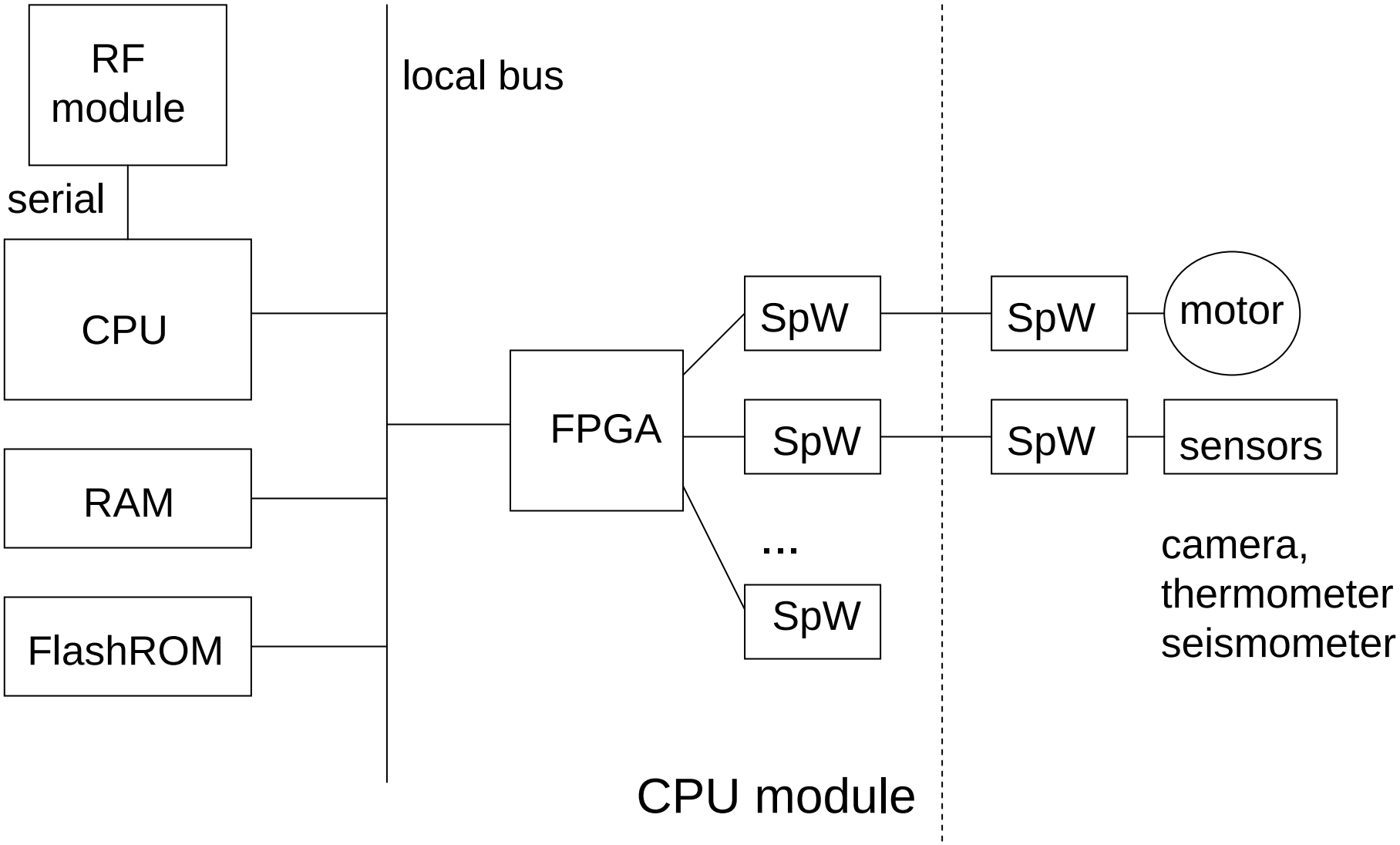
Don Quijote
(ESA)

- Network bus is not necessary. But for making various probes fast and cheaply, SpW may be one solution for sensor I/F
  - CPU modules are always identical.
  - Sensors are connected by SpW I/F to the CPU module.
  - Sensors are different in mission to mission.
  - Power and thermal controllers are adjusted in mission to mission.



Phobos soil
(Russia)

Next Generation MINERVA



Future Plan of Robotics: Lunar Rover

- weighted in 20-50[kg]
- Network bus is essential for the data handling of this class of S/C.

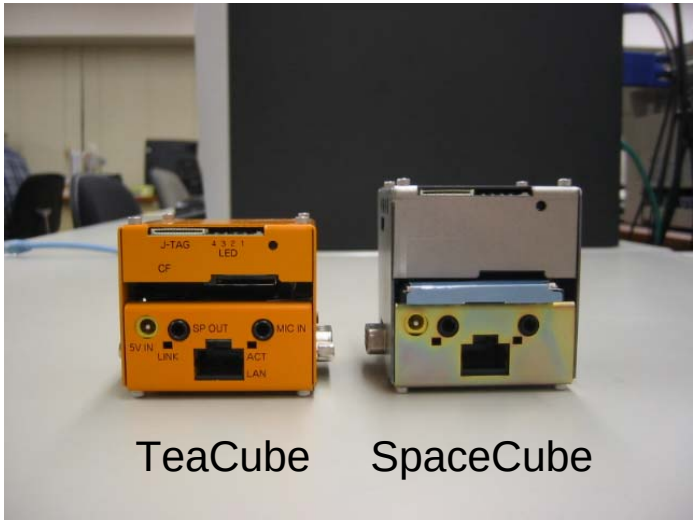
SpaceCube I

Small CPU box provided with three SpaceWire I/Fs based on TeaCube (a commercial product)

Specifications

- size: 52[mm]×52[mm]×55[mm]
- mass: 220[g] (not including a power supply)
- CPU: VR5500CPU (clock: 200MHz)
- OS: T-Engine (successor of iTRON)
  Linux
- color: black

- I/F:.
  - SpaceWire×3 ports
  - USB×2 ports
  - Compact Flash
  - VGA (display)
  - RS-232C serial port
  - LAN
  - Headphone, Microphone



TeaCube SpaceCube

Notice

- Not guaranteed a use in space.
- You can make a presentation and listen to music.

SpaceCube II

- Space-proof CPU board provided with SpaceWire I/Fs
- Not a cube. Looks like a M*c Mini

148mm

148mm

CPU board

*M*c Mini:165mm x165mm x 51mm, 1.3kg

SpaceCube II

Specifications

- size: 148mm x 148mm
- height: 40mm (stacked by CPU board and IO board)
- CPU: radiation-proof MIPS based 64bit CPU developed by JAXA
  (processing speed: max of 200[MIPS])
- power: 10[W]
- OS: T-Engine
- I/F
  - SpaceWire I/F × 6 ports
  - LAN
  - serial: RS232c × 2 ports, RS422 × 2 ports

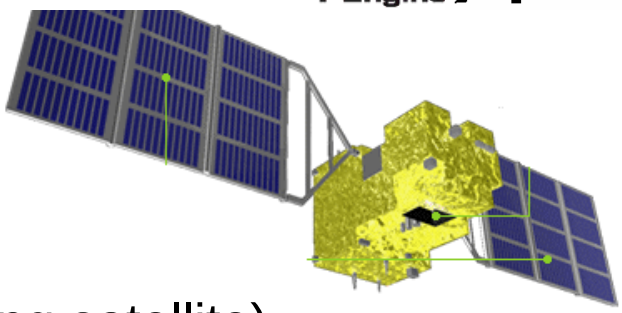
Notice

- will be usable in space.
- You can neither make a presentation nor listen to music

• Current Status

- Prototype model was fabricated
- Installation of OS is being conducted and will be completed in August

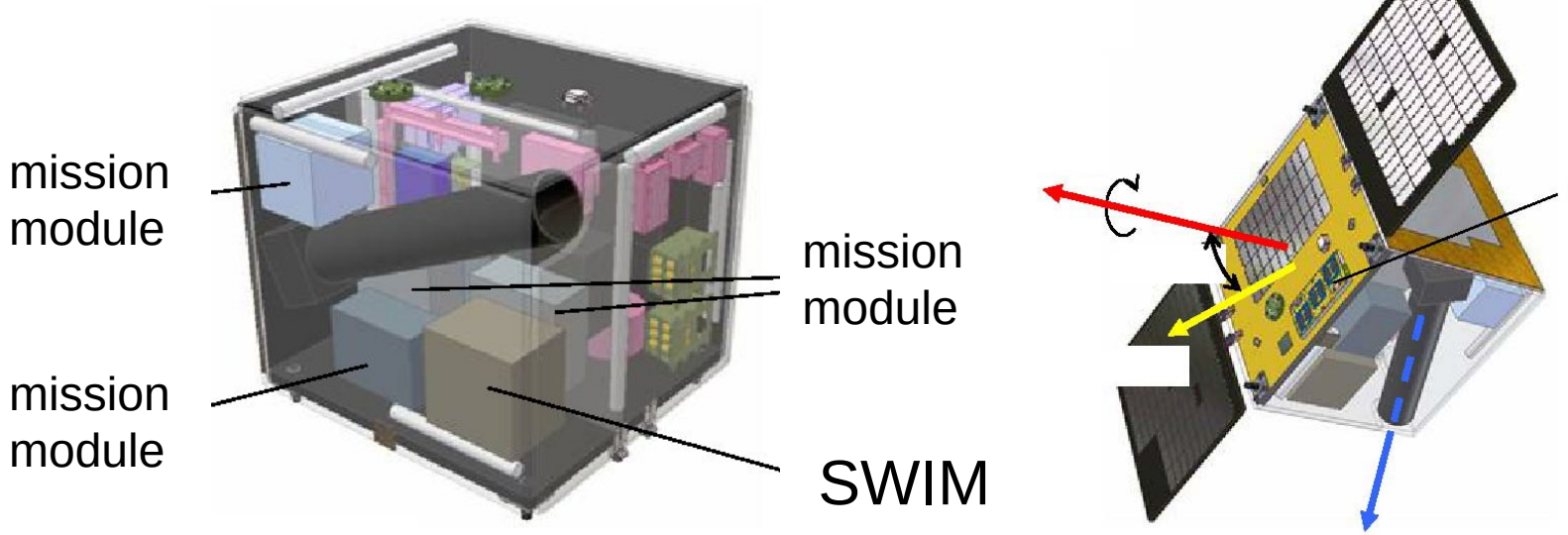
Demonstration by Piggyback Satellite



- Launch: Summer, 2008
- vehicle: Japanese H-IIA rocket
- main satellite: GOSAT (1650[kg], Earth observing satellite)
  There is a large extra cargo space
- orbit: Sun-synchronous polar orbit (altitude: 666[km])

- Piggyback satellites to be launched
  (1) Engineering small satellite by JAXA
    - 100[kg] class
    - SpaceCube II will be installed
  (2) Small satellites from the general public
    - Public announcement of call for satellites was published on 10/May/2006 by JAXA only in Japanese.
    - weight: 1 - 50[kg]
    - application due: Aug.2006

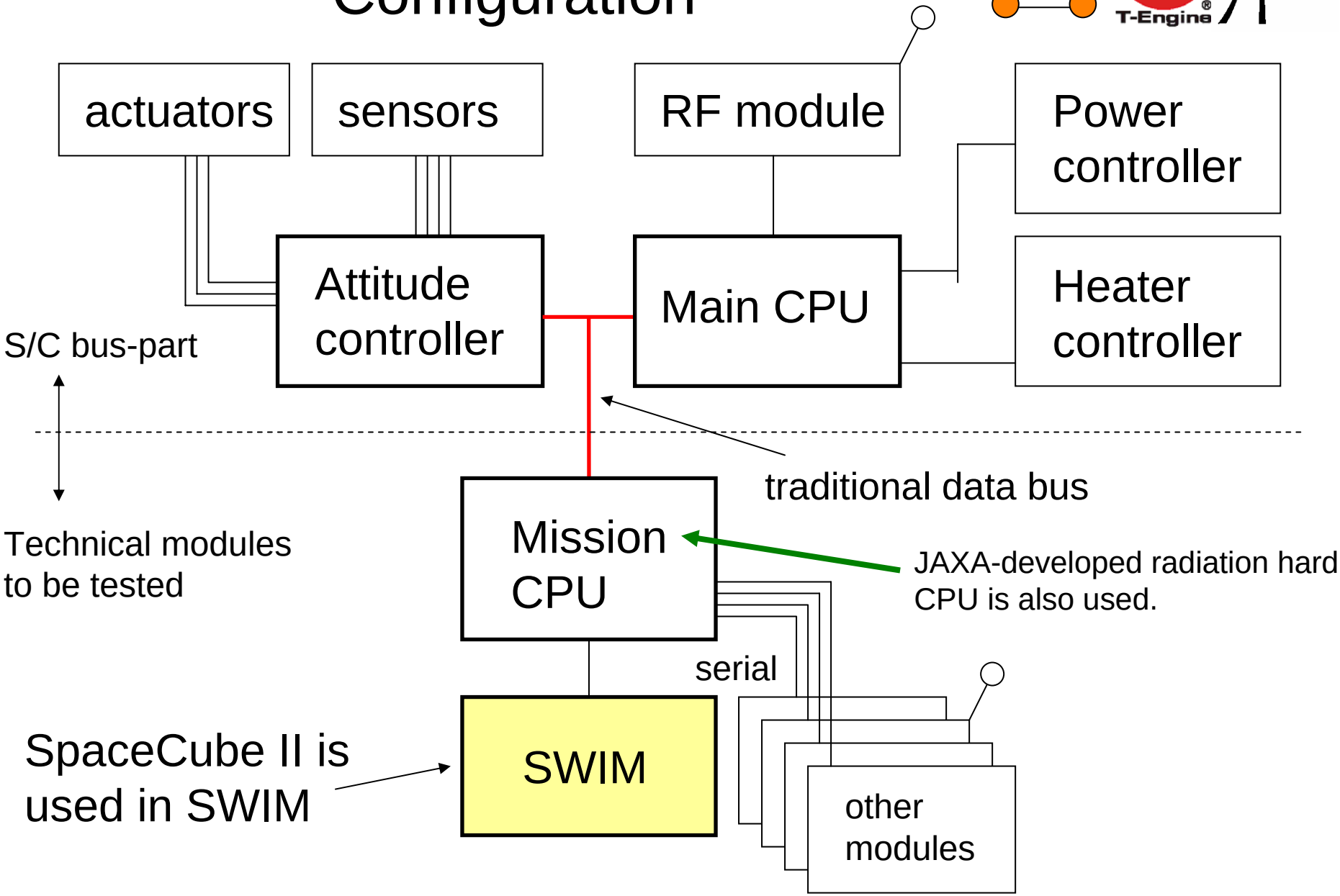
JAXA Engineering Piggyback Small Satellite



one of the current designs

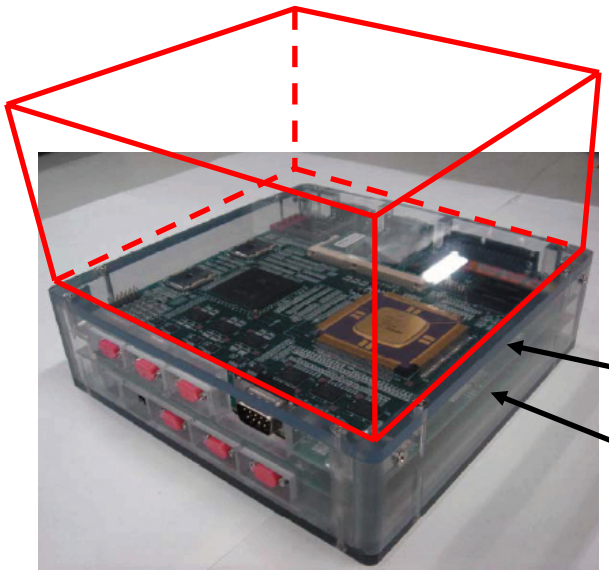
- New technical functions are tested and demonstrated by the satellite based on a matured components.
- SWIM (SpaceWire Interface Module)
  composed of the SpaceCube II and the sensor sub-module

JAXA Engineering Satellite Configuration



SWIM (SpaceWire Interface Module)

- size: 200mm x 200mm x 150mm
- mass: 5.0[kg]
- power: 25[W] (including loss by DC-DC)
- What SWIM do?
  - Obtained data by a couple of sensors are transmitted by SpW to SpaceCube II.



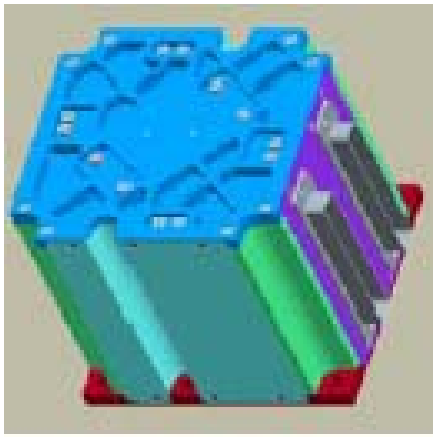
sensor part

SpW power

SpaceCube II

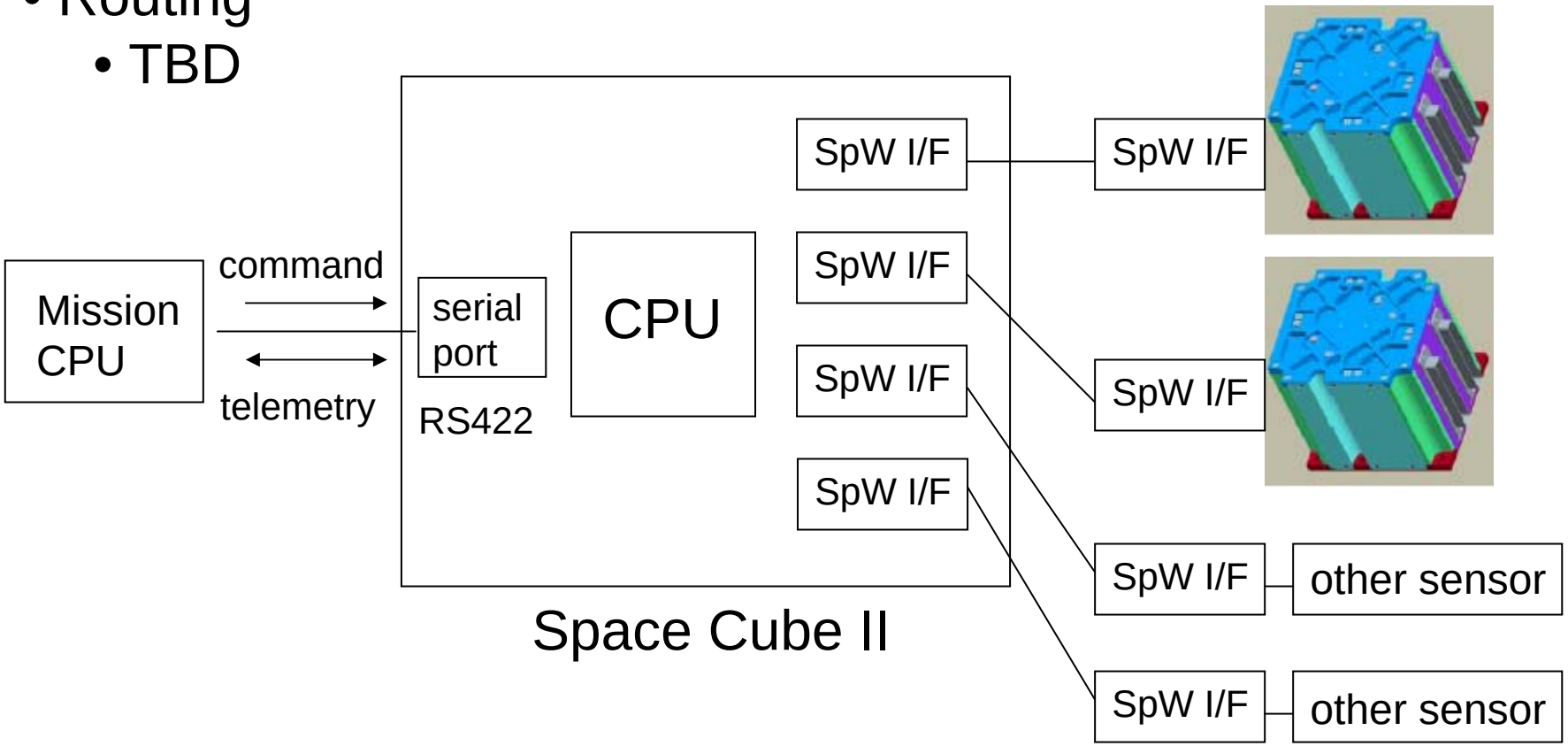
IO board, Power controller

CPU board



SWIM Configuration

- Sensors
  - two Gravitatinoal wave detector
  - measurement of environment
- Routing
  - TBD



Summary

- Future rover project in Japan may use SpW
  - as a sensor I/F in Pico-sized small probes.
  - as a main databus in Lunar rovers.

- Space Cube I (CPU box with SpW I/Fs)
  Use in space is not guaranteed.
- Space Cube II is being developed.
  It can be used in Space.

- We are planning to demonstrate SpW in space
  by a piggyback satellite launched in 2008
  including Space Cube II

Proceed to Prof. Nomachi